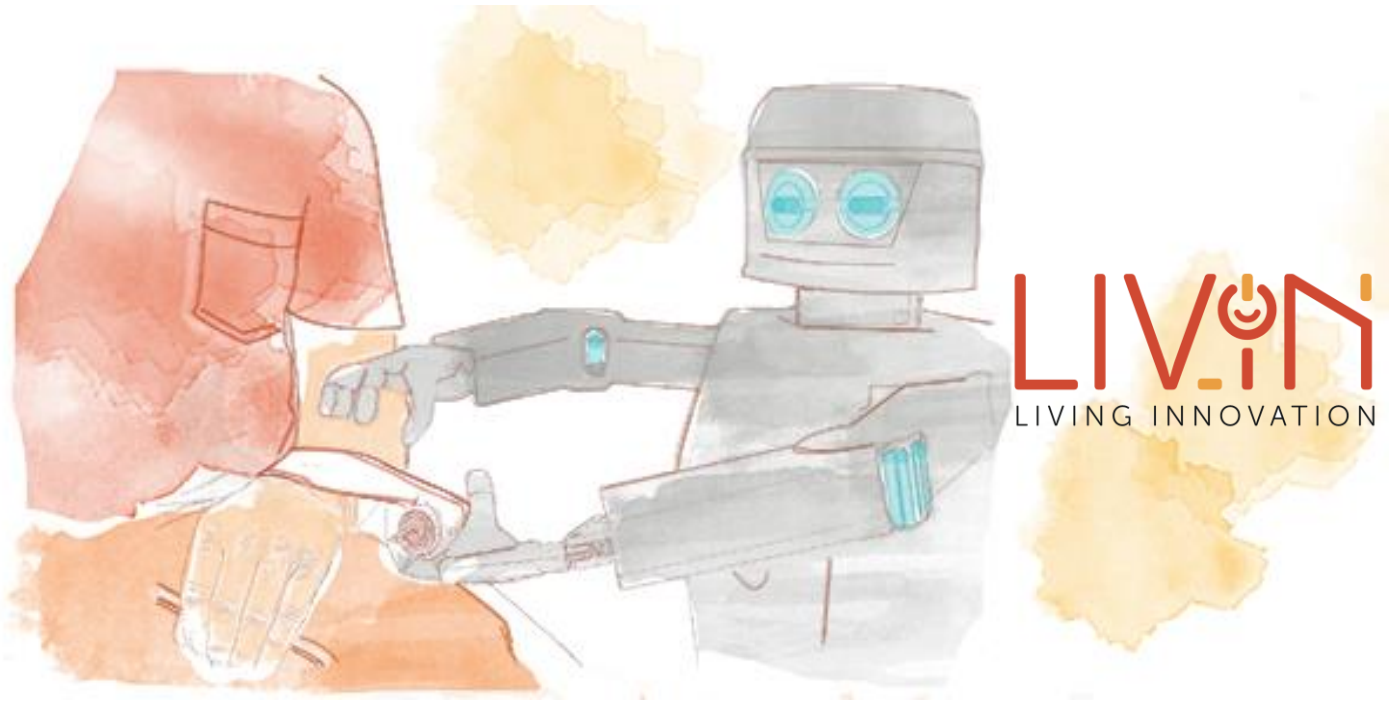

LIVING INNOVATION

Social Robotics

Definitions and challenges

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List of acronyms

MIT	Massachusetts Institute of Technology
HAUS	Humanoid Robots in Architecture and Urban Spaces
AIST	National Institute of Advanced Industrial Science and Technology
GDPR	General Data Protection Regulation from the European Union

1. Introduction

Understood as a place for living, smart homes include sensors, actuators and equipment seamlessly connected to enhance the lives of its residents. In this case, social robotics plays a major role thanks to its various facets. The social consequences of robotics depend to a significant degree on how they are employed by users inside their homes. To a compelling degree, also on their evolution from a technical point of view.

Social robotics as a term, involves *humanoid* and *animaloid* forms. Their shape is of fundamental importance, as it affects the objects emotional interaction with users. While browsing through the internet, one can find differing definitions of social robotics and note the sparkled debates surrounding the topic. To prevent further misunderstandings, the following research will start providing a distinction of the term. Additionally, we will explore how social robotics can contribute to one's life, what kind of products are available on the market now or in the near future, and the restrictions that may occur whilst using robotics[1].

2. Definitions

Social Scientist Dr. Kate Darling, a leading expert in Robot Ethics and researcher at the MIT Media Lab, regards a social robot as a "physically embodied, autonomous agent that communicates and interacts with humans on an emotional level […] Social robots also follow social behavior patterns, have various 'state of mind', and adapt to what they learn through their interactions."[2]

Similarly, Terrence Fong, Illa Nourbakhsh and Kerstin Dautenhahn, provide another definition for social robots. Therefore, understanding them as "robots for which social interaction plays a key role" and which "express or perceive emotions, communicate with high-level-dialogue, recognize models with other agents, establish and maintain social relationships, use natural cues like gaze or gestures, exhibit distinctive personality and character as well as may develop social competencies."[3]

H.A.U.S., as a research group, brings together experts from automation technology, AI research, architecture, human robot interaction, performance art and Philosophy. Given their diverse backgrounds, the group explains that the terminology to describe the so-called social robots is not consistent across literature but depends on the particular research emphasis. A general definition is proposed and it notes social robots as "a physical entity embodied in a complex, dynamic, and social environment sufficiently empowered to behave in a manner conducive to its own goals and those of its community".[4] As a result, the unique characteristic of this robot is its ability to interact in a correct manner with both, other robots and human beings.

Considering the wide range of applications that social robotics can be faced with, the next step here is to highlight its role within the smart home context. As a result, the main areas considered are as follows: the support of elder populations in the form of entertainment and health care, supporting children with their intellectual development and the sex toy industry.

"A PHYSICALLY EMBODIED, AUTONOMOUS AGENT THAT COMMUNICATES AND INTERACTS WITH HUMANS ON AN EMOTIONAL LEVEL […] SOCIAL ROBOTS ALSO FOLLOW SOCIAL BEHAVIOR PATTERNS, HAVE VARIOUS 'STATE OF MIND', AND ADAPT TO WHAT THEY LEARN THROUGH THEIR INTERACTIONS."[5]

[1] Campa 2016
[2] Id.
[3] Fong, Nourbakhsh & Dautenhahn 2003
[4] https://h-a-u-s.org/index.php/2015/10/27/what-is-a-social-robot/
[5] Id.

2.1 Elder Care

Joost Broeken, Marcel Heerink and Henk Rosendal, explain that assistive social robots could play an important role in the health and psychological well-being of older populations. The authors note that while robots can have a wide range of applications, the assistive characteristic at the core of eldercare makes certain devices more useful than others. Additionally, mentioning the difference between assistive social robots and assistive robotic devices. While the former focuses on service and company, the latter takes up the function of physical rehabilitation.[6]

In this regard, assistive social robotics is highlighted because of its possible functional and affective roles. On the one hand, as the devices help build an interface between the needs of elder groups and digital technology. On the other, for their positive influence in the quality of life of a segment of the population in need of companionship and support. Additionally, the authors suggest the existence of different studies that report positive reactions of this segment towards assistive social robots. Their research also suggests some evidence that companion types of robots have positive effects in health eldercare as they observe changes in mood, loneliness and social connections.[7]

2.2 Child development

In terms of kids learning engagement, Jacqueline M. Kory Westlund from the MIT media lab, presents evidence that robot social behaviors tend to have a significant impact. Among these behaviors, the author notes the following: nonverbal (e.g. gaze and posture), social contingency (e.g. performing the right social behaviors at the right times), and expressivity (e.g. using a very expressive voice versus a flat/boring one).

Kory Westlund mentions that in most of these studies, robots are deliberately placed as a child's peer. The idea behind it is to use familiar elements to a child's learning process such as observation, cooperation and conflict with their peers. As a result, a cute and fluffy robot was placed in a peer-like role seemed like a natural option for the author's research. Over the past six years, these research considerations led to the observation that kids tend to mirror robot behavior and language. Most importantly, leading to the conclusion that this segment of society may learn from robots on a similar manner than they do from their peers.

2.3 Sex industry

Chantal Cox-George, Junior Doctor at St George's Hospital NHS foundation trust and Susan Bewley, Professor of the Women's Health Academic Centre of King's College London, note that the sex technology industry is already placing at an estimated USD 30 billion. In this regard, the authors also mention that sex toys are well-established products. In addition, the authors note that sex robots that include anthropomorphic characteristics are also created for sexual gratification purposes. Thus, suggesting that these products have made a leap from science fiction to reality evidenced by Four companies are mentioned as involved in the commercializing of adult robots, or so-called 'sexbots'. Mostly, with prices ranging between USD 5000 and USD 15000.

The sex robot market appears to be composed in its majority by men and there is a prevalence of 'female' features in adult bots design. However, the company Realbotix is for their interest in designing and selling 'male'-looking devices8. Given these developments, the medical profession needs to be prepared for inevitable questions about the impact of sex robots on people's health. Apart from free-market profits, the majority of arguments rely somewhat defensively on the use 'harm limitations' to convince others that this is one way to protect the vulnerable. Opponents would reject the hypothesis that they help reduce sexual crimes and instead raise concerns about

[6] Broekens, Heerink & Rosendal 2009.
[7] Id.
[8] https://sciencetrends.com/realistic-male-sex-+robots-bionic-penises-will-go-sale-year/

the potential dangers. Especially, if it promotes the pervasive idea that real women are similar to sex objects, constantly available as their robot counterparts. Furthermore, helping intensify existing patterns of physical and sexual violence against women and children. This and other aspects leave clear that the sex robot industry is not only controversial, but also involves mere buyers and providers.

3. Social robots: availability and challenges

Given the definitions above, the following section will focus on a selection of products available on the market that feature both the humanoid and animaloid characteristics of common social robots. Therefore, citing the following cases: ElliQ, Pepper & NAO, Jibo, Buddy, Paro, Milo and Lynx.

3.1 ElliQ

ElliQ is an AI-powered social robot designed for older adults. Its aim is to keep its users active and engaged by proactively suggesting engaging activities and making it simple to connect with loved ones. ElliQ seamlessly connects its users with their family and friends and makes it easy for them to take full advantage of the latest online content and services without complexity and frustration. Consequently, the device provides a way for older adults to reap the benefits of technology without the need to master the tools. Along the way, it adapts to the personality and interest of its individual senior, so ElliQ can recommend digital content they may enjoy such as news, music, TED talks and cognitive games. It communicates through body language, speech, sounds, light and images in order to suggest outdoor activities, medicine intake or calls to family members. In order to offer a complete profile of the product, the company's website offers the user a downloadable version of the press kit and other detailed informations on ElliQ. [9]

3.2 Jibo

Founded in 2012, the company Jibo Inc. is primarily known for creating the eponymous robot Jibo, cited as the first social robot for homes. Jibo Inc. officially launched its robot in 2017 after nearly three years of development and optimization at its headquarters in Boston, Massachusetts.[10] While the project raised more than USD 3 million, it faced lay-offs and delayed shipments during 2018. The latter notably affected international orders due to its lack of operations in countries other than the US and Canada. All, despite originally taking orders from customers in 45 different countries around the globe. Another challenge faced by the company was the unexpected amount of cheaper and skilled competition that led to a series of Jibo knockoffs.[11]

Jibo is marketed as a helpful presence in the home and is priced at USD 899. It is built to interact and communicate with people around him using advanced Natural Language Understanding along with speech and facial recognition. According to the company's Website, the robot is able to recognize 16 different people and answer everyday life questions, including weather and traffic forecasts. Thus, hoping to forge relationships with the different members of the household who use it to set alarms, play music, take photos, tell jokes and offer information from the web. Also, including a program that allows children to learn code while practicing problem-solving and computational thinking activities.

[9] https://elliq.com/pages/press
[10] https://www.jibo.com/about-us/
[11] https://www.therobotreport.com/jibo-social-robot-analyzing-what-went-wrong/

Similarly, the robot's founders advertise its ability to optimize the smart home's IoT devices through IFTTT integrations. Some of their examples include controlling lights, thermostat and even brewing coffee. However, the constraint with this format is that you need devices from a specific partner company in order to enjoy Jibo's complete palette of functionalities.[12]

3.3 Pepper & NAO

NAO is the first humanoid robot created by SoftBank Robotics and it has been gradually improving since the beginning of 2006. Currently in its 6th version, more than 13000 NAOs are being used in over 70 countries around the world. NAO is an interactive and customizable robot that has become a benchmark in the world of research, education, healthcare (e.g. retirement homes or hospitals), retail and tourism. The robot serves as a research source, a tool for making teaching and learning fun, a platform for developing applications, a tool to ease interaction with children with autism, or an innovative interface to provide customers with information.

Its robotic brother Pepper is a social humanoid robot capable of understanding and reacting to a basic set of human emotions. Pepper can welcome customers, drive traffic, give product and service information. Beyond that, it serves as valuable source of consumer behavioral data. Therefore, the robot is often advertised for its ability to redefine customer experience and is offered mostly to companies and public institutions, like hospitals and schools.

The website of SoftBank Robotics, the development company of Pepper, states that its main fields of application are the assistance in retail, finance, government, healthcare, tourism, education and research. While Pepper is available for consumers in Japan, in Europe only companies are offered a chance to buy it. However, Soft Bank Robotics declares in its website that its aim is to make robots accessible to everyone and let them become daily companions. Therefore, suggesting for them a role of human-shaped supporters of people's daily activities.

3.4 Buddy

Buddy is the brainchild of Rodolphe Hasselvander, CEO and Founder of Blue Frog Robotics. Before this venture, Hasselvander was the executive director of CRIIF, a private research laboratory in robotics. The team obtained their funds through fund raising and presold more than 1000 units. The price was set at USD 699 during its 2015 Indiegogo campaign.[13] By 2018, CNN Money reported a price of around 1550 US Dollars for the robot.[14]

As any other social robot designed to serve as a friendly companion at home. Its main fields of application are communication, companionship, home security, smart home, education, gaming and eldercare. Some of its abilities include, making video calls, sending and reading messages from family members. It also serves as a reminder, alarm clock and to-do list. The main focus though are the possibilities it offers to check up on your home remotely in order to detect events like fires or burglars.

The device can be used to control other smart home devices like lights, door locks and thermostat via voice-control. Additionally, it offers learning activities for kids like counting, storytelling, memory and programming apps. Buddy provides social interaction with the elderly and assistance by monitoring their homes for unusual activity as well as reminding them to take their medication. Furthermore, Buddy is supported by an open platform where a developer community can work with the robot's concept and push it to new possibilities. Overall, aiming at democratizing the field of robotics.[15]

[12] https://www.jibo.com/; https://www.jibo.com/skills/
[13] https://www.indiegogo.com/projects/buddy-your-family-s-companion-robot#/
[14] https://www.indiegogo.com/projects/buddy-your-family-s-companion-robot#/
[15] https://buddytherobot.com/wp-content/uploads/PRESS_KIT/Buddy-Press-Kit-EN.pdf

3.5 Milo

Milo was created by Texas-based Robokind, also known as robots4autism. The product itself is still in the pilot and research phase, which limits public access to the robot's functions.[16] The sales operations manager of Robokind, Jeff Goodman, notes that they would sell Milo only for use in schools and therapy centers and is currently unavailable for private citizens.[17]

Milo is a humanoid robot designed to teach social skills to children with autism. It can smile, laugh, walk and speak. The focus is mostly placed on developing a teaching tool for educators, therapists and parents to support kids in the elementary and middle school age. The robot was not designed to replace people, but rather to as a way of improving teaching and learning environments. Its focus is to teach children how to behave in different social situations. Thus, supporting them with aspects like self-motivation, self-regulation, interaction and the understanding of facial expressions and social cues. In order to do so, the robot collects learning data from its students.[18]

3.6 Lynx

The social robot Lynx is the product of UBTECH Robotics. As a Chinese industry leading AI and human robotics company, its mission is to bring a robot into every home and truly integrate intelligent devices into people's daily lives. Founded in 2012, it has successfully developed several consumer humanoid robots similar to Lynx and achieved an estimated value of USD 5 billion in 2018.[19] Lynx is able to trigger events such as greetings or music based on the way the user stands in front of him or via voice commands. It can sing, dance, control lights, teach yoga, make video calls, take pictures, videos or live streams, check the weather or traffic, schedule appointments and dinner reservations as well as functions as a calendar and email organizer.

Furthermore, you are able to connect it to Amazon Alexa and use its Avatar & Surveillance mode for home security purposes. The latter allows the user to check remotely on their homes, their pets and even join virtually some family events. With full integration of Alexa, it offers Amazon shopping using simple voice commands. According to customers' test reports, the battery of Lynx serves for one hour and with standard actions, it holds for two hours. In order to recharge it, the user will have to wait for a full two hours. At the moment, Lynx is available on Amazon for USD 799.[20]

3.7 Paro

Paro is an advanced interactive robot developed in 1993 by Dr. Takanori Shibata, Senior Research Scientist at AIST.[21] Paro's design responds to Shibata's interest in documented benefits of animal therapy in different kinds of medical patients thanks to the familiarity and relaxation they evoke. This aspect informed the robot's animal features and its interest in fulfilling two aspects: therapy and the chance to own a pet that can live long. It considers the difficulties at environments such as hospitals and extended care facilities, where live animals become logistically troublesome. Therefore, focusing its attention on a device that can support medical and nursing care without undermining the social interactions that patients long for.[22]

Paro can learn to behave in a way that defined by the user and it responds to this pattern. The robot includes specially developed sensors in order to recognize the manner in which it is being touched. If pet, Paro will remember the behavior and try to repeat that same process in order to be

[16] https://www.rockybay.org.au/news/milo-oct16/
[17] https://www.robokind.com/
[18] https://abilitytools.org/blog/meet-milo-a-social-robot-like-no-other/
[19] https://www.ubtrobot.com/pages/about-ubtech
[20] https://www.businesswire.com/news/home/20170105005107/en/UBTECH-Unveils-Lynx-Video-Enabled-Humanoid-Robot-Amazon
[21] https://www.cfiec.jp/wf/magazine/0771/0771_E.html
[22] Id.

touched once again. A series of prototypes were tested in order to guarantee a body that would be safe and can withstand constant interaction with a human. Paro's interaction with people involves head, tail and eyes, followed by baby harp seal sounds. The animaloid robot is presented by Shibata as a friendly visual and tactile experience that results in positive psychological effects on patients. Especially, regarding their relaxation and motivation.[23] While initially created to bring support and joy to senior citizens with dementia, Paro's function nowadays has extended to a wider range of users.

4. Areas of discussion

After the showcase of some of the available devices, the following section focuses on ongoing discussion topics in the field of social robotics. Such areas involve controversial developments as well as suggestions raised within the social robotics community.

4.1 Data integrity

Robert van den Hoven van Genderen, director of the Center for Law & Internet at Vrije Universiteit Amsterdam, notes that AI and autonomous robots will become part of our future society. Consequently, stating that our physical and informational integrity will be invaded and that the current GDPR describes the protection of personal data during processing in an outdated terminology, especially concerning AI. Due to the non-technological orientation and the hinge on conventional directions of thinking, the author considers that GDPR will not be sufficient in protecting personal data.[24]

Additionally, it is noted that there might be a big risk of chilling effects on the development of AI and robotics if the GDPR is enforced on all AI applications. One of the author's conclusions is that the regulatory gaps will continue to grow unless laws keep their pace with technological advances. Law enforcement will probably not be able to police and regulate future technology accordingly.

The suggestion is to create a system to be protected from AI and autonomous robots before super intelligence creates it for us. How we act now may decide the future we will confront. The author regards a robot as nothing else than an AI system and declares that these concepts are increasingly interrelated.

The difficulties of controlling the processing of personal data of human beings by autonomous or independent robots is definitely raised by van den Hoven van Genderen. The solution offered is the development of algorithms that exclude further processing of personal data from human beings beyond the defined functions of the robot. However, the existence of self-learning autonomous robots makes it challenging to control these processes.[25]

Ramesh Subramanian, professor of information systems at Quinnipiac University, agrees that there is a tremendous privacy risk based in a social robot's constant interaction with their environment. Especially, regarding the continuous transfer of large amounts of data in and out of a system. The author mentions that that in the case of social robots, data is not just environmental and contextual, but also specific to the humans linked to the device. It is also suggested that these datasets could include potentially sensitive health and financial information. Given this context, Subramanian mentions the usefulness of developing security standards that involve biometric methods and help tackle some of the robot's design issues. [26]

Bibi van den Berg, expert in cybersecurity governance, addresses the concerns above with a controversial idea. The position argued is that all privacy issues in the context of social robots will automatically disappear if they are simply kept disconnected from the internet. The author also

[23] http://www.parorobots.com/index.asp
[24] van den Hoven van Genderen 2017
[25] Id.
[26] Subramanian 2017

adds that breaches of private information occur thanks to both, connectivity and cloud processing of the available data. As a result, she recommends connection to the web only during exceptional cases where network connections are a critical requirement for the robot's functionality. Furthermore, van den Bergh notes the importance debating the network needs of social robots. Mostly, suggesting that we are still able to prevent privacy and security problems at the current state, whereas the remedy will be hardly attainable once the devices have reached mass-market.[27]

4.2 Code of Ethics

With the continuously increasing developments in the fields of social robotics, the question arises, whether there is a need of a Code of Ethics for our mechanical companions. Going further, one has to question if humans should attribute them certain legal rights. While many people think that such issues are still outside of discussion, renowned researchers like Kate Darling from the MIT Media Lab examines subjects of this nature. The author suggests that studies of human-robot interaction would show that humans tend to treat social robots as if they were alive. Although people know that they are machines, social robots are able to trigger empathy when incorporating movements, language, and facial features in their design. Therefore, robots that are able to mirror human or animal behavior.[28]

Paul Dumouchel and Luisa Damiano, both professors of philosophy and authors of the book "Living with robots", think that it is essential to define ethical guidelines when dealing with human-robot interactions. How we actually choose to live with social robots, the types of emotional exchanges we have and the progress and direction in which social robotics develops, will inform us overtime on how guidelines take shape and evolve. Furthermore, challenging the traditional account that human cognition is the only type of cognition that should have to be replaced. The authors argue that humans and robots have different types of cognitive architecture, but neither is better or worse than the other. Designers and general actors behind this process hold a great responsibility on the direction and quality that the human-robot relationships will ultimately take.[29]

On that point, another important question comes to one's mind, namely, whether humans should allow social robots to simulate emotions to ease nonverbal communication. In general terms because robots cannot feel emotions as humans do, showing or simulating feelings could be considered as lying. Indeed, it is arguable to which extent machines understand emotions like the loss of a loved one. One can even say that these devices do not give authentic responses to questions because AI only selects the best fitting answer to create an illusion of understanding. It seems clear that many people look at robots and automated devices with a certain fascination and a willingness to attribute physical and mental skills far beyond the machines' actual capabilities. However, it remains as a clever illusion rather than as a real ability.

The list of such ethical aspects to consider when addressing social robots is subject to continuous updates. Questions will continue to emerge around topics like a robot's right to citizenship or to start a business. Therefore, extending interest on the scenarios when humans would working for robots and how would the money generated would be distributed. Similarly, when asking what would happen if a human destroys a social robot, would it receive a punishment? In general, deeper consideration on the relationships with social robots have a potential impact on society. Furthermore, fostering the reassessment of aspects like the extent of a human's right to treat robots like simple commodities and note the chances of matching robot rights to those of animal and even, certain human rights.[30]

[27] van den Berg 2016
[28] https://www.media.mit.edu/articles/do-robots-need-a-code-of-ethics/]
[29] https://blogs.sciencemag.org/books/2017/11/07/living-with-robots/?r3f_986=https://www.google.at/]
[30] https://affective-lab.org/de/social-robots-a-workshop/]

4.3 Synthea Amatus

The robotics company Synthea Amatus was founded in 2015 by Sergi Santos as a frontrunner in the dubious industry of sex robots. Santos, an expert in artificial intelligence with a PhD degree in Nanotechnology from the University of Leeds, developed under this name a number of different sex robots equipped with AI. Before this endeavor he was a well-respected expert and lectured at Yale University. His latest venture is aimed at revolutionizing the sex tech industry by selling his proudest creation Samantha to sex shops across the globe.[31] Synthea Amatus' website offered three different AI sex dolls with a price of EUR 6.000 per unit, as well as three different "normal" sex dolls that priced at EUR 2.295 per unit.[32]

[31] https://www.dailystar.co.uk/news/latest-news/672709/sex-robot-Sergi-Santos-who-is-sex-robot-news-Synthea-Amatus-Samantha-doll-Barcelona
[32] http://syntheaamatus.com/shop/

5. Bibliography

Broekens, J., Heerink, M., & Rosendal, H. (2009). Assistive social robots in elderly care: a review. *Gerontechnology*, *8*(2), 94-103.

Campa, R. (2016). The rise of social robots: a review of the recent literature. *Journal of Evolution and Technology*, *26*(1).

Fong, T., Nourbakhsh, I., & Dautenhahn, K. (2003). A survey of socially interactive robots. *Robotics and autonomous systems*, 42(3-4), 143-166.

Emergent AI, Social Robots and the Law: Security, Privacy and Policy Issues. *Subramanian, Ramesh (2017)" Emergent AI, Social Robots and the Law: Security, Privacy and Policy Issues," Journal of International, Technology and Information Management*, *26*(3).

van den Berg, B. (2016). Mind the air gap. In *Data Protection on the Move* (pp. 1-24). Springer, Dordrecht.

van den Hoven van Genderen, R. (2017). Privacy and Data Protection in the Age of Pervasive Technologies in AI and Robotics. *European Data Protection Law Review*, 3, 338.

6. Additional links

1) An informative article that emphasizes the psychological point of view within the social robotics context:

   https://www.apa.org/monitor/2018/01/cover-social-robots

2) A well-written scientific paper focusing ethical consequences of social robotics in general and sex robots in particular:

   https://sigai.acm.org/static/aimatters/3-4/AIMatters-3-4-11-Wagner.pdf

3) The room document for the 38th International Conference of Data Protection and Privacy Commissioners (ICDPPC). ICDPPC is a worldwide annual forum at which independent regulators on privacy, data protection and freedom of information adopt high level resolutions and recommendations addressed to governments and international organization:

   https://edps.europa.eu/sites/edp/files/publication/16-10-19_marrakesh_ai_paper_en.pdf

4) An interesting research paper from renowned scientist Cynthia Breazeal et al about measuring young children's long-term relationships with social robots:

   https://dam-prod.media.mit.edu/x/2018/04/25/KoryWestlund-IDC18_grxKCvX.pdf

5) An article from Frank Tobe, Founder of The Robot Report, that summarizes well some facts, the hype as well as legal and ethical considerations of sex robots:

   https://www.therobotreport.com/sex-robots-facts-hype-legal-ethical-considerations/

6) An academic paper that aims to draw a review of the recent literature concerning the rise of social robotics:

   https://jetpress.org/v26.1/campa.htm

7) Among all overviews that try to summarize the state-of-the-art on the social robotics market found, the following is in my opinion the most valuable one:

   https://medicalfuturist.com/the-top-12-social-companion-robots

8) A report from the policy department of the European Parliament with the aim of providing information on the legal and ethical issues raised by developments in robotics and AI:

   http://www.europarl.europa.eu/RegData/etudes/STUD/2016/571379/IPOL_STU(2016)571379_EN.pdf